AMENDMENTS TO THE SPECIFICATION

Please replace paragraph 0051 with the following paragraph:

[0051] The second stage includes driven pulley 148, which is rigidly coupled to first amplification pulley 144 and is positioned such that second belt 154 is wrapped around pulley 148, as indicated by dashed line 149.The assembly of pulley 144/pulley 148 is rotatably coupled to ground member 104a, 104b and other ground member 105a, 105b. Second amplification pulley 152 is rigidly coupled to extension member 106 of the gimbal mechanism 100. Second belt 152 is wrapped around transmission pulley 148 and second amplification pulley 152, and is routed around the active idlers 150 which are located at intermediate positions between pulleys 148 and 152 as shown. Active idlers 150 are positioned such that the belt 152 is routed between the driven pulley 148 and the active idlers 150. Active idlers 150 are in constant rolling action with the second belt 154 to increase the belt wrap angle (i.e. to increase the number of teeth engaged). Belt 154 preferably includes teeth on one side or other gripping features that engage teeth of driven pulley 148 and amplification pulley 152

Please replace paragraph 0076 with the following paragraph:

[0076] If the filter is not to be applied, the Filtered value determined by process 214 is set equal to the ReportRaw sensor value that was input to the process 256, and the ReportRaw value is then returned to the main process 200, i.e. no filtering is performed. The process is then complete at 258. If the filter is to be applied, then in step 254 the Filtered value is set equal to the result of a filtering function F which has an output based

on the inputs of the (previous) Filtered value and the Report Raw sensor value. The function F can be any function that has been found to effectively filter out the overshoot data. For example, a single pole digital lowpass filter can be used. Since the overshoot is a short, momentary event, the low pass filter will filter out any such high frequency data by comparing the previous Filtered value with the ReportRaw value; when a large change is shown between them (high frequency), the ReportRaw value is set to a value closer to the previous value according to the filter; such types of filters are well known to those skilled in the art (e.g., the Filtered value = Filtered value + k(ReportRaw - previous Filtered value), where k is a constant less than 1). Once the filter is applied, the Filtered value is returned to the main process 200 of Fig. 6 and is stored as Filtered Raw Value, and the process is complete at 258.

Please replace the Abstract of the Disclosure with the following paragraph:

Improvements in accurately sensing a user manipulandum of a force feedback device. A force feedback device, coupled to a host computer, includes an actuator for outputting ~~forces oil~~forces on a manipulandum and a sensor for detecting a position of the manipulandum. In one feature, a raw sensor value representing manipulandum position is adjusted based on compliance between sensor and manipulandum, where the adjustment can be based on a compliance constant and an output force. In another feature, a range of motion of the manipulandum is dynamically calibrated from startup. One boundary value of an assigned initial range is set equal to a received sensor value if the sensor value is outside the initial range, and the other boundary value is adjusted to maintain the size of

the initial range unless the other boundary value has already been sensed outside the initial range. In another feature, manipulandum position is accurately sensed by filtering raw sensor values for overshoot values occurring at limits to manipulandum motion and using the filtered value in the dynamic calibration. In another feature, sensing inaccuracies caused by compliance in the device are decreased by normalizing a raw sensor value to a normalized range of motion that includes a saturation zone at each end of the range that adjusts sensor values over a saturation level to the saturation level.

Please replace paragraph 0047 with the following paragraph:

[0047] Gimbal mechanism 100 is formed as a five-member ("five-bar") closed chain. Each end of one member is coupled to the end of another member. The five-bar linkage is arranged such that extension member 106a, central member 108a, and central member 108b can be rotated about axis A in a first degree of freedom. The linkage is also arranged such that extension member 106b, central member 108b, and central member 108a can be rotated about axis B in a second degree of freedom. A similar structure is also disclosed in co-pending patent application 09/138,304~~________~~, filed concurrently herewith, by Bruneau et al., entitled, "Improvements in Mechanical and Force Transmission for Force Feedback Devices", now U.S. Patent No. 6,400,352~~Atty. Docket No. IMMIP049~~, and Patent No. 5,731,804, both of which are incorporated by reference herein.

Please replace paragraph 0053 with the following paragraph:

[0053] The belt drive mechanism 114 provides a mechanical advantage to the output forces of actuators 62 so that the force output of the actuators is increased. The ratio of the diameter of pulley 144 to the diameter of pulley 140, and the ratio of the diameter of pulley 152 to pulley 148, dictates the amount of mechanical advantage, similar to a gear system. Since there are two stages, each providing amplification to the forces output by actuator 62, the total amplification to the forces is the product of the amplification provided by each stage. The belt drive system of Fig. 5 is described in greater detail in copending application 09/138,304 , by Bruneau et al., entitled, "Improvements in Mechanical and Force Transmission for Force Feedback Devices", now U.S. Patent No. 6,400,352~~Atty. Docket No. IMMIP049~~, previously incorporated herein by reference.

Please replace paragraph 0078 with the following paragraph:

[0078] The present invention provides an initial range at startup that is significantly smaller than the full range of the device and at the same time large enough that the default centering spring gains are stable. The device can assume that the manipulandum is centered in this initial range at startup. Then, as the manipulandum position changes, this initial range is then updated and changed according to actual sensed device limits, as described in the process 218. As described above, the initial range is preferably about one-half the approximate range of the raw sensor, although the initial range can be other sizes in other embodiments. The process 218 begins at 280, and in step 282, the process checks whether the size of the current range (Max - Min, where Max = the current maximum and Min = the current minimum) is less than or equal to the size of the initial range. The initial range is indicated in FIGURE 8a, which represents a linear range of

motion of the manipulandum in one degree of freedom for explanatory purposes, where O indicates the startup origin of the manipulandum. If the current range is greater than the initial range, then the current range has already been increased by a previous iteration of this process or process 222, and step 290 is performed, described below. If the current range is less than or equal to the initial range, then the process continues to step 284, in which the process checks whether Max is less than or equal to the initial maximum value set in the initialization step 204. If Max is greater than the initial maximum value, then the current range has already been increased by a previous iteration of the process 222 of Fig. 9, and the process continues to step 290, described below. If Max is less than or equal to the initial maximum, then in step 286 the process checks whether the Filtered Raw Value is greater than or equal to a point one-half the distance of the initial range below the initial minimum (the point Min2 in Fig. 8a), i.e., whether the raw value is still within a range that is twice the original initial range centered about the startup origin (or a distance equal to the initial range below the origin). If the Filtered Raw Value is less than the point ~~Mint~~Min2, then step 290 is performed, described below. If the Filtered Raw Value is greater than or equal to the point Min2, then step 288 is performed, in which Max is set equal to the Filtered Raw Value plus the initial range, i.e., the new Min plus the initial range. In step 290, Min is set equal to the Filtered Raw Value, and the process is then complete at 292.

Please replace paragraph 0085 with the following paragraph.

[0085] FIGURE 10a is a graph showing the relationship between the raw sensor range ~~arid~~and the normalized sensor range, where Min and Max are the limits to the raw sensor

range and True_Min and True_Max are the limits to the normalized sensor range. In an ideal normalization process where compliance does not exist, the curve 366 indicates a direct linear relationship between raw and normalized values. In the present invention, saturation zones are provided such that raw sensor values near the limits Min and Max are not normalized to corresponding values in the normalized domain past a saturation level. Curve 368 shows a normalization curve that can be used by the present invention, in which saturation zones 370 are provided at the extremes of the curve. Thus, any value that would be normalized to a value above True_Max or below True_Min is adjusted to the level of True_Max or True_Min (whichever is appropriate), so that True_Max and True-Min are "saturation levels." The Saturation value used in step 352 is the distance shown in Fig. 10a in the normalized scale at each extreme that extends above the saturation level. For example, in an embodiment using potentiometers a value of 100 can be used for the Saturation value, where True_Max equals 2048, True_Min = 2048, Max 150, and Min = 900). It should be noted that other normalization curves can alternatively be used, such as non-linear curves (e.g., rounded, bent, or stepped functions).

Please replace paragraph 0088 with the following paragraph:

[0088] FIG. 8 is a flow diagram illustrating step 218 of FIG. 6, in which a reset minimum process is performed to set a new minimum limit for the range of the manipulandum and to adjust the current maximum limit, if necessary. This process is used for force feedback devices 12 having relative sensors, since the microprocessor 50 does not know the position of the manipulandum at startup with respect to the actual, physical range of the

device when relative sensors are used; only after the manipulandum has been moved in its workspace does the actual range of the device become apparent. The process of FIG. 8 provides a default range to the manipulandum upon startup and may adjust this default range as the manipulandum moves through its workspace. The default range is a range that is greater than zero, but which is less than the entire range of the device. This is because either a zero range or a large range, if assigned initially, can cause undesirable effects. The zero range (or a range close to zero) is undesirable because of the instability and oscillation that this causes upon startup of the device due to default "software spring" forces provided at startup (the default spring forces output from the actuator are preferably used to center the manipulandum in its workspace even when no actual force sensations are being instructed by an application program, and also when the device is idle). For example, since the entire range of the device would be very small at startup, and since the default spring has a force based on the distance moved in this range, the force will be very large since any tiny motion of the manipulandum will move it across a large portion of its range, which normalizes to a large distance. This translates to a large spring force, which causes the manipulandum to spring back and forth in an oscillating manner until a larger range has been ~~travelled~~traveled through and sensed. A large range is undesirable because the device may startup when the manipulandum is close to a range limit, so that some of the assigned range values are outside the achievable range of the manipulandum.